PROCEEDINGS

International Europhysics Conference on HEP

Experimental and simulation study of the MSGC+GEM detectors

Gilles De Lentdecker[*,†], **Olivier Devroede, Fred Udo, Catherine Vander Velde, Pascal Vanlaer**

IIHE, ULB-VUB, CP-230, Boulevard de la Plaine, 1050 Brussels, Belgium
E-mail: delentdecker@hep.iihe.ac.be

Tom Beckers, Valery Zhukov

Universiteit Antwerpen (UIA), Antwerpen, Belgium

Stéphanie Moreau

Institut de Recherches Subatomiques, IN2P3-CNRS-ULP, Strasbourg, France

Andreas Nowack, Anette Zander

RWTH, III. Physikalisches Institut B, Aachen, Germany

Abstract: We report the results of systematic investigations on operating properties of MSGC+GEM detectors exposed to different sources of X-rays. The influence of the drift field on the detector response has been studied experimentally and by simulation. Charging-up effects depending on the drift field will be discussed.

1. Introduction

The next generation of high energy physics experiments puts severe requirements on their tracking detectors. Modern gas counters have to sustain intense fluxes of minimum ionizing particles (MIP), as high as 10^4 Hz/mm^2, in presence of highly ionizing particles (HIP). These particles are nuclear fragments, produced from strong interactions between hadrons and the detector material, which may induce discharges between the detector electrodes even at moderate gains of a few thousand.

The addition of a preamplification stage in the form of a Gas Electron Multiplier (GEM) [1] to a micro-pattern device may increase substantially the maximum gain sustainable in presence of HIPs [2]. The combination of a Micro Strip Gas Counter (MSGC) [3]

*Speaker.

†Supported by the FRIA, fonds pour la formation à la recherche dans l'industrie et l'agriculture

and a GEM has been adopted by the HERA-B experiment [4] and was envisaged for the Forward outer Tracker of the CMS experiment. The robustness of the MSGC+GEM detectors designed for the CMS experiment has been shown in a large scale test with eighteen such modules [5].

To optimize the operating conditions of the MSGC+GEM detector, we investigated the influence of the drift field on the detector response, experimentally and by simulations. We also report charging-up effects depending on the drift field.

2. Detector and experimental set-ups

The detectors were built following the layout foreseen for the forward CMS tracker [6]. A detailed description of the assembling and commissioning procedures of these detectors can be found in references [5] and [7]. The module has a shape of a sector of annulus. It consists of four trapezoidal MSGCs assembled side by side, covered with one GEM foil stretched 2 mm above the substrates and one cathode drift plane placed 3 mm above the GEM foil. The region between the drift electrode and the GEM is called the drift gap and the region below the GEM is referred to as the transfer gap.

The MSGC substrates have gold strips printed on 300 μm thick D263 glass. The anodes are 7 μm wide and 10 cm long, with a pitch ranging from 181 to 204 μm, to account for the trapezoidal shape. The cathode width varies from 138 to 158 μm, in order to maintain a constant gas gain along the strips [8]. The GEM is composed of a Kapton foil, 50 μm thick, metallized on both sides and perforated. Due to the etching process the holes are 72 and 38 μm in diameter in the metal and in the middle of the Kapton respectively. The distance between the holes is 120 μm.

The measurements have been conducted with two different irradiation set-ups. In the first set-up, we use a ^{55}Fe source emitting 5.9 keV photons at a rate of 10 Hz/mm^2. The source is collimated on a group of 16 anodes connected to a charge amplifier, ORTEC 172PC. In the second setup, we use an X-ray gun producing 8.3 keV photons at a flux of up to 10^5 Hz/mm^2. The beam is collimated to a surface of 100 mm^2. In this set-up the anodes are grounded through a 1 MΩ resistor and the current is calculated from the voltage drop across the resistor with an accurate voltmeter, KEITHLEY 182. In both set-ups, the gas mixture, Ar/CO_2-70/30%, is flushed in the detector module at a rate of 1 renewal per hour.

3. GEM transparency

The drift field does not participate directly to the gas amplification but it may affect the measured signal by influencing the charge collection efficiency of the GEM mesh. We define the GEM transparency as the ratio of the number of primary electrons producing an avalanche in the holes over the total number of primary electrons released by the ionizing particle. As the loss of primary electrons can lead to detection inefficiencies, the GEM transparency should be high. The measured gain, called effective gain, is defined as the product of the gas gains and the transparency. Consequently, we investigate the transparency by measuring the effective gain as a function of the drift field, when the other fields are kept constant.

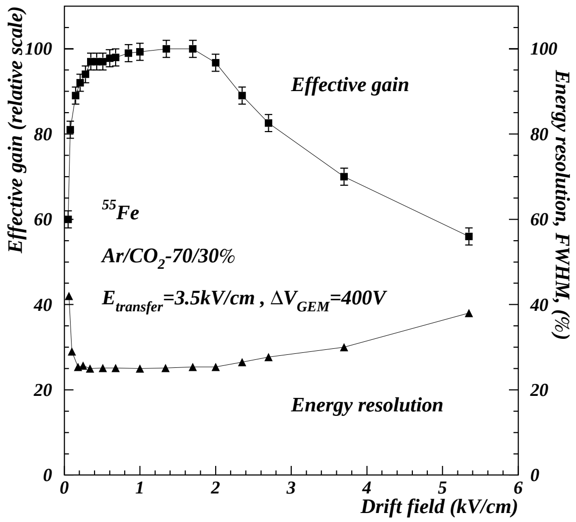

Figure 1: Dependence of the effective gain and the energy resolution (FWHM) on the drift field. The measurement is obtained with a ^{55}Fe source, with a transfer field of 3.5 kV/cm and a potential difference across the GEM of 400V.

Such a dependence is shown in figure 1 for a transfer field of 3.5 kV/cm and a GEM potential difference of 400V. We observe a plateau ranging from 0.5 to 2 kV/cm where the effective gain is maximum and the energy resolution goes through a minimum. The better energy resolution in this range suggests that only a small fraction of primary charge is lost. Beyond a drift field of 2 kV/cm, the relative gain decreases and the energy resolution degrades. This effect is attributed to a decrease of the transparency with increasing drift fields.

The influence of the drift field on the transparency is confirmed by three dimensional calculations of the electric field. These calculations are performed with two interfaced programs: MAXWELL [9] and GARFIELD [10]. Figures 2 and 3 represent field lines and equipotentials into a plane crossing one GEM hole, for two different field configurations, keeping the potential difference in the GEM at 400V. Figure 2 represents an operation mode with a drift field of 1 kV/cm and a transfer field of 3.5 kV/cm. As all field lines from the drift region enter the GEM holes, we can suggest that the GEM transparency is close to a 100%. When the MSGC+GEM detector is operated at higher drift fields, some field lines from the drift region may terminate on the upper GEM electrode, therefore reducing the transparency. This behaviour is illustrated on figure 3 for a drift field of 7 kV/cm and a transfer field of 3.5 kV/cm.

4. Charging-up effects

With the X-ray tube (see section 2) we investigated the transparency by recording the currents on the different electrodes as a function of the drift field. With this method we observed a significant decrease of the recorded strip current at drift fields between 0.5 and 1.5 kV/cm, compared to the maximum current recorded at 2 kV/cm. This decrease of the effective gain is in contradiction with our previous measurements (see figure 1) and with the field simulations which predict an optimum transparency at low drift fields (see section 3).

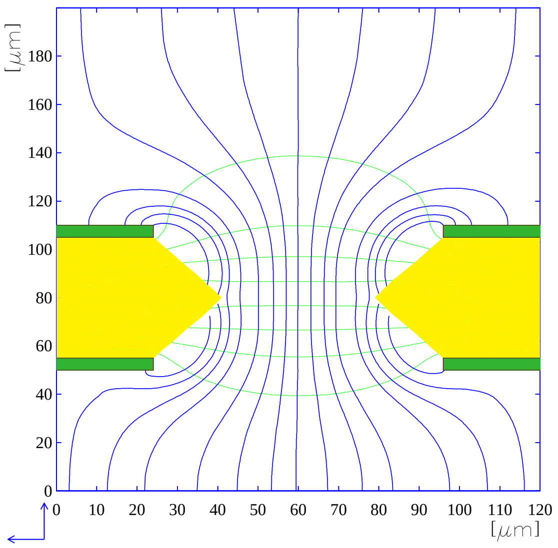

Figure 2: Field lines and equipotentials around a GEM hole, with a potential difference of 400V, with a transfer field of 3.5 kV/cm and a drift field = 1 kV/cm.

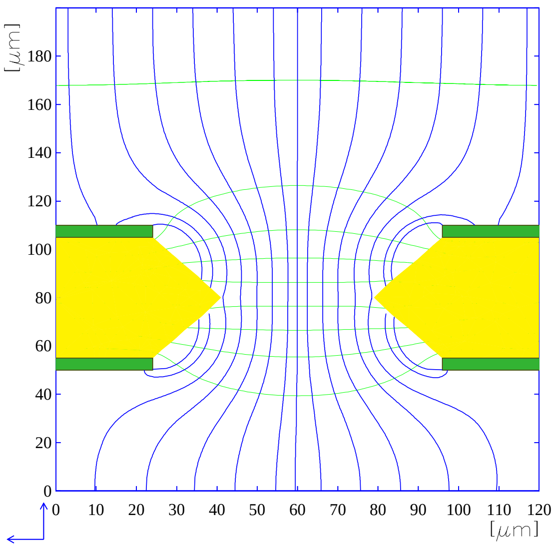

Figure 3: Field lines and equipotentials around a GEM hole, with a potential difference of 400V, with a transfer field of 3.5 kV/cm and a drift field = 7 kV/cm.

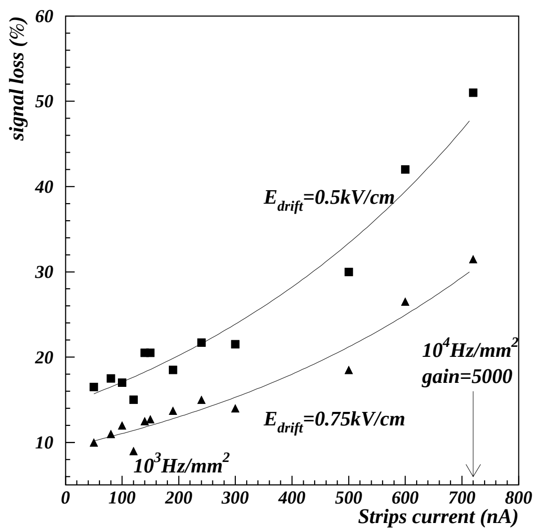

Figure 4: Loss of the effective gain as a function of the strips current at drift fields of 0.5 kV/cm and 0.75 kV/cm.

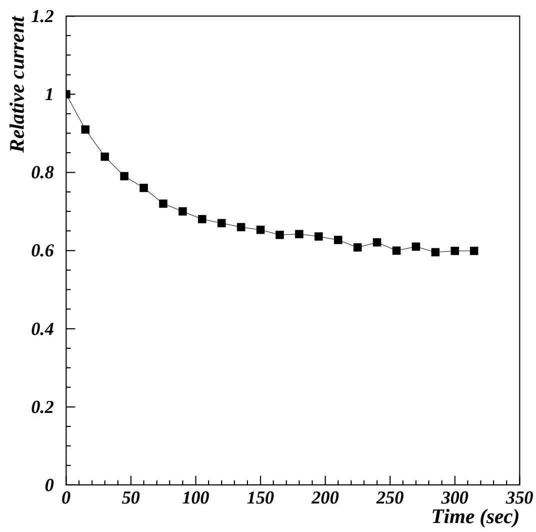

Figure 5: Relative strip current as a function of time when the drift field is reduced from 1.0 to 0.5 kV/cm, with a maximum current of ∼500nA.

The signal loss has been investigated by recording the anode current for drift fields below 3 kV/cm, in various conditions of irradiation rate and gain. The rate was varied from 10^3 to 10^4 Hz/mm^2 and the gain, from 1000 to 5000. Figure 4 shows the signal loss as a function of the maximum current for two drift fields, 0.5 and 0.75 kV/cm. We clearly observe the influence of the total charge produced in the detector on the measured current. With a drift field of 0.5 kV/cm, a 50% signal loss is measured at a photon rate of 10^4 Hz/mm^2 and a gain of $\sim$5000. At 0.75 kV/cm, the signal drop is already reduced by almost a factor two.

To find out the source of this gain loss, we investigated the time dependence of the current. Figure 5 shows the evolution of the recorded current when the drift field is reduced from 1.0 to 0.5 kV/cm with a maximum current of $\sim$500nA. The long time constant of the drop, several minutes, suggests that this behaviour is due to the charging of an insulator. Indeed electron-ion recombinations are not expected at electric fields as high as 0.5 kV/cm. Moreover the clean gas system, used for ageing measurements, ensures the absence of electronegative pollutants in the gas mixture. The dependence of the current drop on the drift field indicates that the charging-up occurs on the Kapton of the GEM foil rather than on the MSGC substrate.

It is important to note that this effect does not prevent MSGC+GEM detectors to operate stably at high particle rates over long time periods [5].

5. Conclusions

Systematic investigations on operating properties of the MSGC+GEM detector have shown the influence of the drift field on the detector response. The charge transfer processes through the GEM foil are understood with three dimensional field calculation. We also report signal losses related to the total charge produced in the detector, depending on the drift field. They are attributed to the charging-up of the Kapton layer in the GEM.

References

[1] F. Sauli, *Nucl. Instrum. Meth.* **A 386** (1997) 531

[2] A. Bressan et al., *Nucl. Instrum. Meth.* **A 424** (1999) 321

[3] A. Oed et al., *Nucl. Instrum. Meth.* **A 263** (1988) 351

[4] T. Zeuner et al., *Nucl. Instrum. Meth.* **A 446** (2000) 324

[5] M Ageron et al., *Nucl. Instrum. Meth.* **A 471** (2001) 380

[6] CMS collaboration, The Tracker Project, CERN/LHCC 98-6, 1998

[7] Dirk Macke, Micro Strip Gas Chambers with Gas Electron Multiplier and their applications in the CMS experiment, PITHA 01/00

[8] O. Bouhali et al., Proceedings of the International Workshop on micro-pattern gas detectors, p9, Orsay, June 99.

[9] MAXWELL, Ansoft Co Pittsburg PA, USA

[10] R. Veenhof, *Nucl. Instrum. Meth.* **A 419** (1998) 726